Civil and Environmental Research
ISSN 2224-5790 (Paper) ISSN 2225-0514 (Online)
Vol.8, No.11, 2016
www.iiste.org

Assessment of Water Supply and Demand of Boditi Town

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Abstract
This study was done to look at the gap between current water supply and demand of Boditi Town and to indicate the future water demand. VENSIM model to assess water supply, water balance method to estimate water loss, geometric growth method for population estimation, numerical criteria ranking method to assess water source option were used in the study. Based on the findings, the averaged current water consumption (L/c/d) of the Town, for public tap users, for private tap users and in-house connection were 14.7, 6.2, 20.4 and 37 respectively and the water supply coverage of the Town was at the level of 74%.The average water loss of the system rated to be 34.4%. The current water production was estimated to be 231,309 m^3/year and the projected water demand for 2023 estimated to be 752,263 m^3/year. This indicates that, water supply has to be raised by 520,954m^3/year. The gap between water supply and demand can be narrowed through demand based supply and supplementing the existing supply with additional sources. Presence of additional water sources to supplement the current supply was indicated by measuring the annual discharges of four not yet unused springs: Seeson, Shaamina, Bolo and Woysha having annual discharges exceeding 80,000 m^3/yr, 55,000 m^3/yr, 400,000 m^3/yr and 30,000 m^3/yr respectively. It was identified that the performance of water supply system is low. Compared with Universal Access Plan, disparity between supply and demand should be closed through supplemental water source.
Keywords: Water supply, water demand, supply coverage, Boditi Town.

1. Introduction

According to the Federal Democratic Republic of Ethiopia report, investment in water supply has increased from 1.19 billion birr in 2005 to 1.66 billion birr in 2010, however, access to water supply increased from 68.5% to 81.5% for urban and 65.8% for rural (Water Aid, 2010 and AMCOW, 2009/2010). Globally the percentage of people served with water supply rose from 79% (4.1 billion people) in 1990 to 82% (4.9 billion people) in 2000 and at the beginning of 2000 one-sixth (1.1 billion people) of the world's population was without access to water supply, majority of the people live in Asia and Africa(UNICEF/WHO,2000). Concerning water supply coverage, Ethiopian Government has determined to adopt Universal Access Plan to achieve 98% access for rural and 100% for urban water supply and sanitation by 2012 (MoWR,2006). However access to water supply for rural within 1.5 Km which is 15 L/c/d is estimated to 54% and for urban within 0.5 Km which is 20 L/c/d is estimated to be 86% (Gelebo, 2008).

High population growth and development of urban centers depend on limited water resources. The current global population is estimated to be 6.9 billion people, of which 82% live in developing countries, yet the water resources have remained constant, and receiving an increasing load from growing population (UN-Habitat, 2009). Urban areas are increasingly facing challenges of providing water services for the growing urban population and economic activities (Sam, 2006). Growing population will further increase the demand for water and there are limited cost-effective water supplying augmentation options (Dharmaratna *et al.,* 2010). Water supply augmentation requires a number of years for planning, huge amount of capital, trained man power to have reliable water supply. Worldwide are facing perceived water shortage due to increasing demands on water from all sectors (Mollinga, 2006). This indicates that, water is becoming scarce and its demand is increasing over for various uses.

1.1 Objective

The objective of this study is to indicate the gap between drinking water supply and demand.

2. Method and Materials

2.1 Description of the study area

The study was conducted at Boditi Town which is located in Damot Gale Woreda, SNNPR regional state, Ethiopia, having a total area of 1368.115 ha. Geographically, it is located: 6º56'0" to 8º58'0" N Latitude and 37º50'0" to 37º53'0" E Longitude. The Town is at an altitude ranging from 1880 m to 2112 m. The Town is 365 km from Addis Ababa and 140Km from Hawassa.

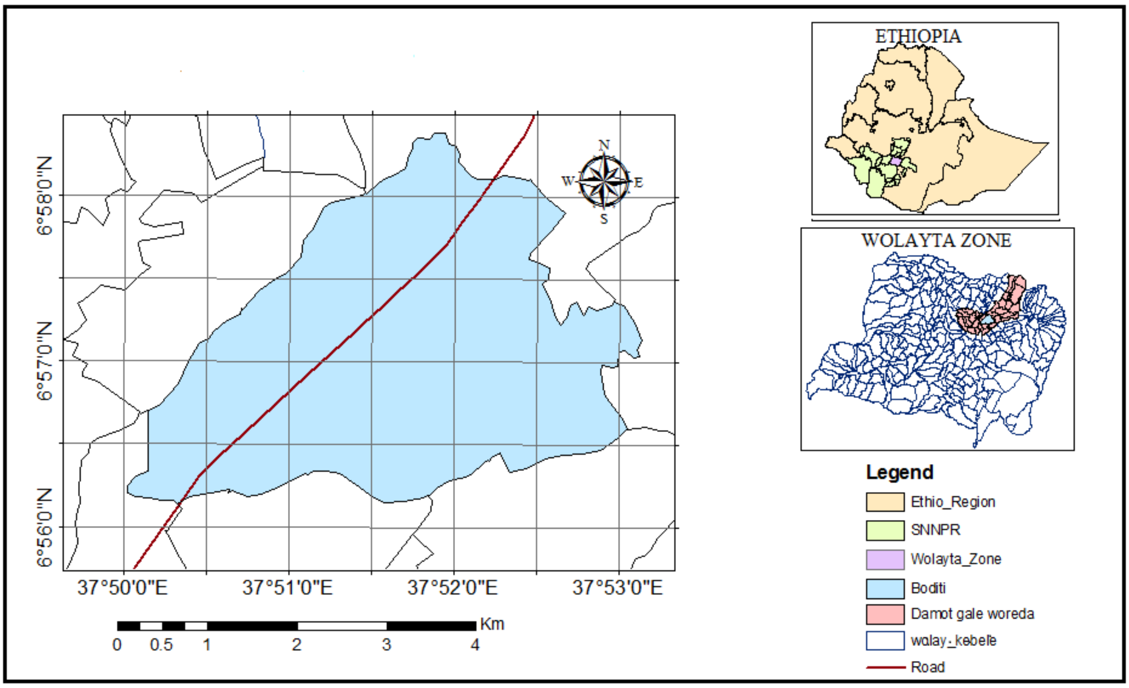

Figure 1: Location map of Boditi Town.

2.2Performance indicators used in the study

Performance indicators are variables whose purpose is to measure change in a process, i.e, monitoring the progress of a process, or performance indicators are used to assess the change resulting from a particular activity, i.e, evaluating the outcome of the process. The complete group incorporates about 133 indicators, of which 26 have been rated as top priority (Algre *et al*, 2000). In this study, four major groups of performance indicators used are indicated in the table below.

Table 1: Performance indicators of the study.

Performance indicator	Description	Selected target
Water production/supply	Supply to meet demand, m^3/day or L/c/d	20 L/c/d (MoWR, 2009; WHO, 2000)
Water consumption/demand	Supply to meet demand, m^3/day or L/c/d	20 L/c/d (MoWR, 2009; MDG) from 0.5 Km fetching distance.
Water loss/UfW	Volume of water lost as percentage of water supplied.	20% (Tynan and Kingdom, 2002; Mwanza, 2004; MDG)
Water supply coverage	Access to drinking water supply service.	100% (MoWE, 2011; WHO/ UNICEF, 2000)

Note: The selected targets are based on the Universal Access Plan of Ethiopia.

2.3 Water production of the Town

The Town gets its water supply from four boreholes. The water is pumped from the boreholes and reaches consumer premises by pump and gravity flow. Based on the aggregate operating time and actual discharges of each borehole, the daily, monthly and yearly water production was calculated by the relationship:

$$V_{prod(L)} = BH_{disch(L/_s)} \ X \ BH_{working\ time(s)} -------------- (1)$$

Where, V_{prod} = total volume produced by the borehole in liters, BH $_{disch}$ = discharge of borehole in liter/second and BH $_{working\ time}$ = aggregate working time of the borehole in seconds.

2.4 Water supply assessment

Urban water balance has been developed using the VENSIM dynamic modeling Shell (VENSIM, 1998). The Ventana systems Environment (VENSIM) platform was chosen for developing water balance. In this method water enters the city from various surface water sources and ground water withdrawal as measured (1950-2004) or projected (2004-2030) over the whole period analyzed (Van Rooijen et al., 2005).

2.5 Water consumption

Billing records are usually used to quantify water consumption. Billing records is equivalent to the consumption that can be used for water balance calculations (Welday, 2005).The yearly water consumption has been aggregated from the private connected, public taps, in-house connected, institutional and commercial center meters.

While water consumption data was reviewed, differences in some consecutive months were observed. This difference might be caused by non-regular readings of the meters. In such cases, the water enterprise has designed checking mechanism and new meter installation practices. As observed from monthly individual water consumption, on one hand large consumption and on the other hand small consumption were seen. Despite this variation, the aggregated values were not affected much as the lower and higher individual values can be balanced to each other. To calculate the daily water consumption, the annual water consumption was converted to average daily per capita consumption and by using population data of the Town (Welday, 2005).

$$W_{Cons}(liter/person/day) = \frac{Annual\ consumption(m^3)X1000L/m^3}{population\ number of the Town X\ 365} ------(2)$$

Where, W_{cons} = per capita water consumption in liter/person/day. The average daily per capita consumption was used to indicate the water supply coverage of the Town.

2.6 Water loss estimation

Based on registered data (system input volume and consumed volume) the water loss was estimated i, e. system input volume is the sum of authorized water consumption and water loss (Radivojevic et al., 2008; Kammer and Van der, 2003) .

The total water loss of the Town was quantified based on the total annual water production that was aggregated from the working hours of the four boreholes and distributed to the system, and the water billed that was aggregated from the customer meter readings. The water balance method was used to estimate the water loss in the distribution system. This method calculates the total water loss in the distribution system from total flows not for a limited time period (Jastin, 1993).

$$total\ water\ loss(\%) = \frac{[W_{tot.prod} - W_{tot.cons(billed)}]X100}{W_{tot.prod}} ------(3)$$

Where, $W_{tot.prod}$ = total water produced, $W_{tot.cons}$ = total water consumed.

2.7 Water demand assessment

Water demand forecasting is component based and the demand is broken down into different components and a baseline demand in every component is assessed from a base year to a particular date in the future (Sutherland and Fenn, 2000). Water demand assessment is the amount of water needed to supply population, i,e. the assessment requires data collection on existing water consumption patterns, number and types of facilities and levels of service in use, potential demand for future upgrading, operation and maintenance arrangements(Parry and Morris,1999; Van Rooijen *et al.,* 2005; Allan *et al.,* 2001). This approach depends on current water consumption, projected population growth, service delivery mode or customer types and demand types. Water demand assessment needs planning the changes with respect to levels and trends in the past and current water consumption.

2.7.1 Housing units and family Size of the Town

The estimated housing units in the Town from Boditi Town Municipality source shows that there are about 7007 housing units, of which 5440 urban and 1567 rural houses, showing ratio of housing unit to population 1: 4.6 (Boditi Town municipality and agriculture unit, 2013 reports).

2.7.2 Service delivery mode and water consumption

The Town's water service delivery has five modes. These are private yard connections, public taps, in-house connections, commercial and institution centers. The per capita water consumption of each customer group/ service level was estimated based on annual water consumption and population data. The level of water consumption by per capita per day was compared for different years.

2.8 Water demand projection

According to MoWE (2011), the Government of Ethiopia produced Universal Access plan to achieve 98% for rural and 100% urban access for water supply and sanitation by 2012, the first phase until 2012 setting per capita consumption rural 15 L/c/d in 1.5 Km and urban 20 L/c/d in 0.5 Km service radius. The target year 2012 was moved to 2016 which would be improved in the second phase and subsequent phase would be adopted. In estimating domestic water demand general design standards were adopted: 30 to 50 L/c/d for urban centers, 15 to 25 L/c/d for rural areas, and the urban domestic water demand is thus projected as being 30 L/c/d for short term, 40 L/c/d for medium term and 50 L/c/d for long term (MoWR, 2002).

The future domestic water demand was based on estimation of water demand per mode of service (2007-2013) and estimated population. Domestic water demand for ten years (2013-2023) has followed the extended UAP (2012-2016), and short term general design of MoWR 2002. Domestic water demand adopted the per capita water consumption to make the demand forecast for the coming 10 years (MoWR, 2002).

$$DWD = P_n XAW --------------(4)$$

DWD= domestic water demand, P_n= population at the target year and AWD = average per capita domestic water demand.

2.8.1 Population projection

Human population is given a great emphasis and studied for various reasons, for example, for resource allocation, socio-economic development, policy implication, adjust situations to existing conditions. The base population data (2013) was obtained from the Zonal and Bodit Town Finance and Development Offices which was established by CSA 2007. In the study, constant population growth rate of 4.7% (CSA, 2007) was assumed and geometrical increase method was adopted for future population forecast. Population projection adapted to geometric growth rate model, in which the growing towns and cities having large expansion (Chatterjee, 2005):

$$P_t = P_0(1+r)^n -------------------(5)$$

Where, P_t = projected population at future time, P_0 = Base population, r = Growth rate in percent, n = number of years.

2.8.2 Commercial and institutional water demand

The water demand of towns include the needs of such commercial and institutional consumers as public schools, clinics, hospitals, offices, shops, bars, restaurants, and hotels. This type of water demand is usually linked directly to population size. For small- and medium-sized towns, population of 30,000 to 80,000, it was estimated at 5% of the domestic water demand, and for larger towns, the estimate was 10% (MoWR, 2002). Since the study Town has a small-sized population, commercial and institutional demand was estimated as 5% of the domestic water demand.

2.8.3 Livestock water demand

The production of livestock is an integral part of a community because livestock are valued assets. Livestock production places demand on water. It is estimated that livestock industries consume 8% of the global water supply, with most of that water being used for intensive, feed-based production (Schlink *et al.,* 2010).Water intake of a livestock depends upon the size, feed, location; and one tropical livestock unit which weighs 250 Kg (live weigh) requires less than 50litres/ day derived from drinking water and moisture in animal feeds (Pedin *et al*., 2002). Dairy cows and beef cattle daily water consumption is in the range of 45-55 liters per day per animal (Waterhouse, 1982). In this study livestock water demand was adopted to be 45 liters per livestock per day.

2.8.4 Average daily demand

Urban average daily demand is considered to be the combined total of demand from domestic, commercial and institutional, industrial, livestock and system losses per day (MoWR, 2002).

2.9 Option assessment

The projected population of the study town may require extra water supply. The projected need for more water means we must examine supply options more strategically (DEFRA, 2008). A numerical criteria ranking method; selection criteria are established and each criterion is weighted based on its relative importance and rating scales (Sutherland and Fenn, 2000; Regional Water supply Outlook, 2009).

In the assessment to decide the most feasible option, five requirements such as yield reliability, benefits (quality), abstraction, risk factor and likely treatment were established. To evaluate the priority of the viable option, each requirement was weighted based on its relative importance with other requirement. For each selection requirement, an option was ranked on a scale of one up to five, with five being the most desirable and one the least [Refer Appendix 1]. Each scale is then given a count of how many times it was preferred over the other scale. The options first ranked, averaged and then percentages were applied. Water supply reliability focuses on the ability of an alternative to provide sufficient water during dry and wet seasons. Quality refers the potable level of water for domestic use. Abstraction refers to possibility of a source to supply system through hydraulic structures. Risk factor refers to accessibility of a source to locate.

The volumes of selected viable option were measured. Volumetric method was used to measure flows/volumes of the springs (Aquino, 2012). The equipment used was timer/ stop watch and a bucket of known volume. The annual total discharges of the four springs were used to complement the existing supply system to balance the future supply and demand of the Town.

3. Results

3.1 Water production and Consumption

The water production of the study Town was from the boreholes and their estimated average yield (L/s): Faate, Keera, Chayna and Dooge 3, 3, 2 and 2 respectively. The aggregate production capacity of the sources was estimated to be 10 L/s.

Based on the discharges and aggregated working time of each borehole, the monthly and annual water productions were estimated by multiplying the actual discharge of each borehole with the total operation time(*Appendix* 2). Data on aggregate working time of daily, monthly and yearly water distributed to the system were collected for duration from July 2011 to June 2013 and shown in Table 2.

Table 2: Monthly and annual volume produced by boreholes (July 2011-June 2013).

Water balance (month)	Volume produced by BH (m^3) (2011/2012)					Volume produced by BH (m^3) (2012/2013)				
	Faate Bh(m^3)	Keera Bh(m^3)	Chayna Bh (m^3)	Dooge Bh(m^3)	Volume Produced (m^3)	Faate Bh(m^3)	Keera Bh(m^3)	Chayna Bh (m^3)	Dooge Bh(m^3)	Volume Produced(m^3)
July	4665	5778	3780	3297	17,520	5918	5983	3672	3182	18,755
Aug	6836	6847	3960	3873	21,516	6264	6080	4140	3837	20,321
Sep	5540	5691	4003	3348	18,582	5929	5130	3780	3794	18,633
Oct	5594	5616	3866	3384	18,460	5832	5907	3614	3729	19,082
Nov	5637	5907	3801	3708	19,053	5724	5292	3852	4176	19,044
Dec	5745	5918	3693	3780	19,136	5637	5918	3960	4068	19,583
Jan	5259	5194	3873	3333	17,659	6156	5812	3924	3844	19,736
Feb	4773	4320	3765	3952	16,810	6058	5346	3772	4017	19,193
Mar	5745	5292	3715	3859	18,611	5616	5886	3816	4039	19,357
Apr	5907	5832	3895	3528	19,162	5648	5540	4053	3780	19,021
May	5842	5875	3866	3672	19,255	5832	5724	4111	3823	19,490
June	5821	5626	3902	3823	19,172	5778	5670	3758	3888	19,094
Total	67,364	67,896	46,119	43,557	224,936	70,392	68,288	46,452	46,177	231,309

The total water production by boreholes in 2011/2012 and 2012/2013 were 224,936 m^3/year and 231,309 m^3/year respectively. Based on Table 2, variation of water volumes in two years were different due to variation in operation time of the boreholes. Water consumption was estimated based on the billing data. The water consumed by different customers was billed which were aggregated from the customers meter reading data. Based on Figure 1 both water supply and consumption were increasing from year to year.

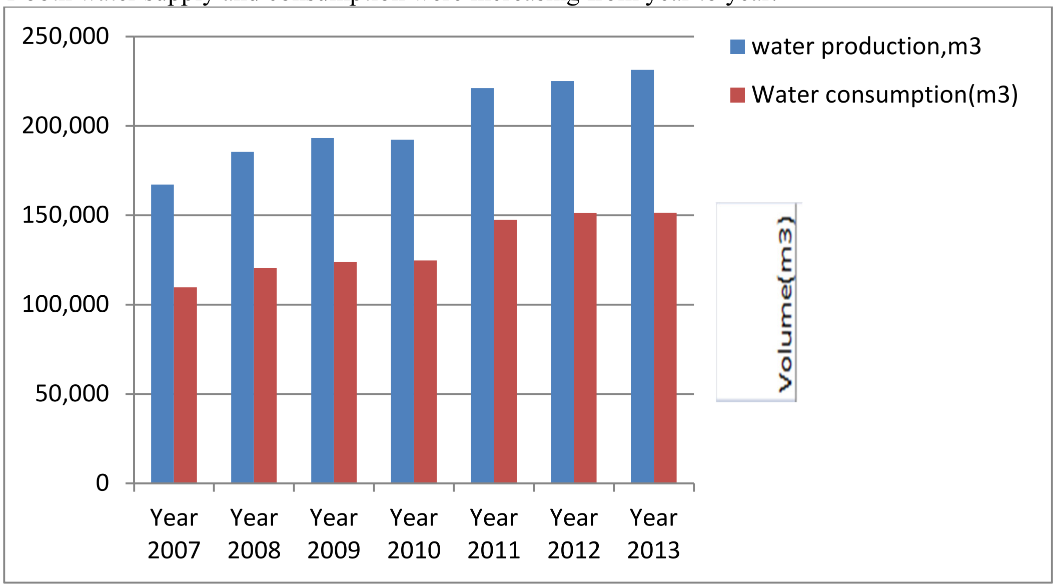

Figure 1: Water production and consumption (2007-2013)

Water production for the supply from 2010 to 2013 indicates that it was increasing, but the change was insignificant. This indicates that a few improvements were made to increase water production.

3.2 Water loss of distribution system.

The total annual water produced and distributed to the supply system and the water billed that was aggregated from the customers meter reading data were used to quantify the total water loss for the Town. The difference between water production and consumption indicator reflects the water loss, which can be rated as a percentage of the difference. Based on the last seven years data collected from Boditi Town water supply enterprise, the water production, consumption and unregistered volumes were estimated shown in Table 3.

Table 3: Water balance of Boditi Town water supply system (2007-2013)

	System input volume (water production, m^3)	Consumed Volume (m^3)	Unregistered volume (m^3)	UFW (Water loss %)
water balance (year)	167,076	109,651	57,425	34.3
Year 2008	185,487	120,420	65,067	35.0
Year 2009	193,032	123,775	69,257	35.8
Year 2010	192,158	124,694	67,464	35.1
Year 2011	221,025	147,456	73,569	33.2
Year 2012	224,936	151,207	73,729	32.7
Year 2013	231,309	151,359	79,950	34.6
Average	202,146	132,995	69,152	34.4

Based on Table 3, both water production and consumption were increasing from 2007 to 2013.The annual water loss increases from 2007 to the end of 2009, and decreasing from 2009 to 2012.In 2013, the annual water produced and distributed to the system within specified year was 231,309 m^3 and the aggregated annual water loss as derived from the above expression was 79,950 m^3 which account to 34.4%. The amount of water reached the consumers for domestic consumption accounts for 65.4% of the total production.

The average water loss as derived from the above expression accounts of 34.4%. Key informants of the Town's water supply enterprise workers were asked about the condition of the enterprise from 2009 to 2012. They confirmed that, organizational management was improved; leak detection and maintenance measures were improved from 2009 to 2012. But for the year 2007 to 2009 water loss was due to lack of maintenance, shortage of resource, and most of the time at the leak points, water moves into the soil, and not moves to the surface.

3.3 Water demand assessment

3.3.1 Pipe connections and service delivery mode

Classification of customers by type or mode of service has the following purposes: indicate future water supply planning, serve for water tariff setting process, suitable for administration. Mode of service and number of connection were shown in Table 4.

Table 4: Connection profiles by mode of service (2007 - 2013)

Customer type	Number of connections						
	Year						
	2007	2008	2009	2010	2011	2012	2013
Private connections	1208	1326	1452	1558	1914	1919	2158
Institutions	48	52	66	72	79	82	88
Commercial centers	195	195	196	199	199	201	203
Public taps	22	22	22	22	23	25	28
In-house connections	16	16	17	18	18	20	22
Total	1489	1611	1753	1869	2233	2247	2497

The connection profile in Table 4 indicates that, the number of new connections from 2011 to 2013 increased by 9.4%. The number of connections increases with development of institutions, small diversified business activities, residence houses. This in turn has increased the water demand in the Town.

3.3.2 Service delivery mode and number of customers

In commercial centers, population estimation only considered persons who live in a commercial center. The Town's water supply enterprise deliver water supply to customer groups and the estimated population shown in Table 5.

Table 5: Estimation of population based on mode of service.

Customer type	Number of population							
	Year							
	2007	2008	2009	2010	2011	2012	2013	Population % (2013)
Private taps	7016	7938	9496	10373	10660	11528	12420	38.9
Commercial	878	878	882	896	896	905	913	2.9
Public taps	11621	11927	11950	12513	13602	14133	14712	46.1
In-house	72	72	77	81	81	90	101	0.3
others							3762	11.8
Total population	24,133	25,125	26,504	27,776	29,109	30,477	31,909	100.0

From Table 5, the number of population in each customer type was increasing from 2007 to 2013. Based on population data 2013, the proportion of people who use public tap accounts 46.1%, private connection accounts 38.9%, commercial center accounts 2.9%, in-house connection accounts 0.3% and people who have no direct access to the supply system 11.8%. The number of population increases with development of institutions, small diversified business activities, and residence house construction. This had increased the water demand in the Town.

3.2.3 Water consumption by customer type

The water consumed by each customer type was estimated on basis of balance sheet and billing data of the Town's water supply service enterprise. The balance sheet clearly indicated that institutional, commercial center, in-house, public tap and private tap water consumption were put in quantifiable numbers. The break down and estimation of Water consumption by customer categories for the last seven years were shown in Table 6.

Table 6: Water consumption by mode of service (2007- 2013).

Customer type	Water consumed in m^3						
	Year						
	2007	2008	2009	2010	2011	2012	2013
Private taps	50886	58082	63475	70840	90325	91031	94182
Institutions	7,307	8,789	10,265	10,989	12,003	15,148	13,236
Commercial	27,977	24,933	19,500	15,405	12,170	10,463	10,258
Public taps	23,433	27,929	29,063	27,897	31,892	32,720	31,528
In-house	579	687	795	919	1,063	1854	2,154
Total	109,651	120,420	123,775	124,694	147,453	151,207	151,359

Based on the Table 6, both total annual water consumption and consumption by customer type were increased over the last seven years. The total water consumption in 2013 accounted to 151,359 m^3, the highest water consumption 62% was accounted for private customers, 21% public tap customers, 9% institutions, 7% commercial, and 1% in-house customers.

3.3.4 Daily Per capita water consumption

The daily water consumption of each customer type was estimated based on water consumed and population number of each customer type. The daily water consumption of each customer type was estimated and shown in Table 7.

Table 7: Per capita per day by mode of service (2007-2013)

Customer type	Water consumption per person per day							Average
	Y e a r							
	2007	2008	2009	2010	2011	2012	2013	
Private connection (L/c/d)	19.9	20	18.3	18.7	23.2	21.6	20.8	20.4
Public taps (L/c/d)	5.5	6.4	6.7	6.1	6.4	6.3	5.9	6.2
In-house connection (L/c/d)	22.0	26.1	28.3	31.1	36.0	56.4	58.0	37.0
Town's average (L/c/d)	14.3	14.8	14.5	13.9	15.7	15.3	14.7	14.7

Water consumption of the study Town was estimated based on the amount of water supplied rather than the actual demand. People having in-house connection service about 0.3% of the total population consumed 37 L/c/d, private yard connection service about 38.9% of the total population consumed 20.4 L/c/d and the remaining population 46% which have access to drinking water are served by public taps use 6.2 L/c/d. In Boditi Town, in-house connection the highest, private tape connection the medium, and public tap the lowest water use. The Town's average 14.7 L/c/d assumed as everyone gets equal amount of water.

3.3.5 Domestic water supply coverage

The water supply coverage of the Town has been evaluated based on the average per capita water consumption. The average per capita water consumption has been derived from yearly water consumption of different customers and their consumption aggregated from individual water meters.

Table 8: Water supply coverage of Boditi Town

Year	Water consumption (m^3/yr)	Consumption per capita (L/person/day)	Water supply coverage (%)
2007	109,651	14.3	71.5
2008	120,420	14.8	74.0
2009	123,775	14.5	72.5
2010	124,694	13.9	69.5
2011	147,456	15.7	78.5
2012	151,207	15.3	76.5
2013	151,359	14.7	73.5

Based on Table 8, water supply coverage increased from 2007 to 2011, and then decreased from 2011 to 2013. The current water supply coverage of the Town was rated at the level of 74%.

3.4 Water Demand Projection

The growth potential of Boditi Town has a basis in which the Town's administration is under effort to provide basic services such as education, health center, residential and commercial houses. Business establishments such as hotels, shops, wood and metal workshops, textile and tailoring, local breweries, urban agriculture in dairy production are becoming increasing in number. The amount of water use is affected by change in population, water use technology, climate, and economic change. Based on these factors, water demand for the future such as domestic demand, livestock demand, institutional and commercial demand was projected.

3.4.1 Population projection

Population of Boditi Town has been increasing rapidly. Population projection of the Town was adapted to the National Statistical Report of Population and housing Census of 2007 by using 2013 population data as a base year with growth rate of 4.7%. Population projection of 2013 to 2023 shown in the Figure 2.

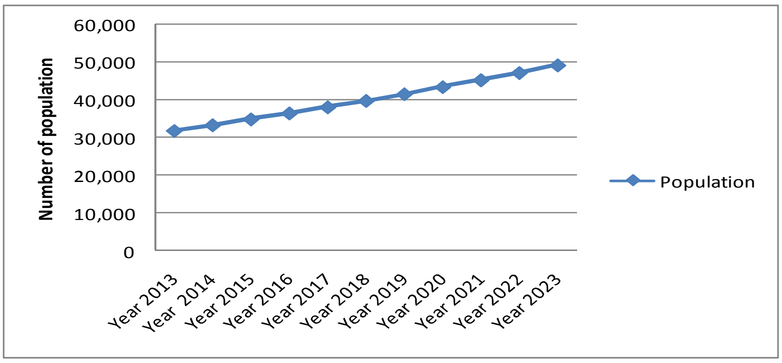

Figure 2: Population growth of Boditi Town

Based on population projection of Boditi Town, population of 31,909 in 2013 is projected to increase to 49,278 by the year 2023, an addition of 17,369 people. Water demand projection of the Town depended on the size of population to be served, institutions and social establishments, commercial activities, and a detailed analysis of past 7 years water consumption trends.

3.4.2 Projected water demand

The Town's domestic water demand projection followed the extended Universal Access Plan for the first five years 20 L/c/d and short term water demand projection 30 L/c/d. Since Boditi Town is classified as category small and medium sized town, commercial and institutional water demand was estimated at 5% of the domestic water demand (MoWR, 2006). The study Town is a peri-urban town which has rural settlements and livestock production is an integral part of a community. Livestock keeping made people to increase income and the proportion of diet such as milk, butter and cheese. Livestock water demand was incorporated in water demand projection.

Table 9: Projected Water demand (m^3/year) for the year 2014 to 2023

Year	2014	2018	2023
Population number	33,409	39,861	49,278
Average per capita domestic water demand (L/c/d)	20	20	30
Domestic water demand (m^3/year)	243,886	280,983	539,594
Commercial and institutional water demand (m^3/year)	12,194	14,549	26,980
Livestock population	3332	3398	3672
Average per livestock water demand (L/livestock/day)	45	45	45
Livestock water demand (m^3/year)	54,728	55,812	60,312
Water loss in system 20% (m^3/year)	62,162	70,269	125,377
Average yearly water demand (m^3/year)	372,970	421,613	752,263

The total projected water demand for 2023 would be 752,263 m^3/year. The current water production was estimated to be 231,309 m^3/year. This indicates that, water supply should be raised by 520,954 m^3/year with in ten years. Therefore, supplementing the existing water supply and reduction of water loss in distribution system is imperative activities.

3.5 Option assessment

Option assessment was done to supplement the current supply system in 2023 due to: established target population, the balance between supply and demand, the level of water loss in the distribution system. Depending upon high future water demand approximately 520,954 m^3/yr of a supplemental water source would be required to meet the projected demand. However, potential supplemental supplies would develop additional water supplies to the Town may include: two rivers, four springs and ground water wells. Two rivers flowing at the territories of Boditi Town, namely Walacha and Cheraqe rivers. Walacha is not perennial river, it flows during rainy seasons. The use of river water for domestic purpose was not recommended due to high treatment cost. Ground water wells or borehole drilling to supplement the current supply may involve reviewing the sub-surface geology, evaluating yield, identifying potential locations for exploration, testing water quality and may require high investment.

3.5.1 Requirements of option

Water source assessment was done based on five selected requirements. The requirements used in option assessment are yield reliability, abstraction, benefits (water quality), risk factor and likely treatment. Each requirement was rated by using rating scales [Refer appendix 1]. Each requirement was first rated by scale, scales averaged; percentages were applied and then ranked to indicate the viable prior water source. To select the most feasible option, quantitative scores of the requirements were shown in Table 10

Table 10: Quantitative scores of requirements

Source	Requirements										Over all Score 100%
	Reliability		Benefits/ quality		Abstraction		Risk factor		Likely treatment		
	25 %	100 %	25 %	100 %	15%	100%	15%	100%	20%	100%	
Springs	4	16	4	16	1	6.67	3	20	4	20	78.67
River	3	12	1	4	1	6.67	2	13.33	1	5	41.00
Ground water wells	3	12	4	16	1	6.67	1	6.67	3	15	56.34

The three water sources: spring, river and ground water wells were compared with five requirements, and springs were more viable option to meet the projected water demand and were chosen as an alternate source of water to augment the existing water supply system in 2023.

Volumetric measurement was used to determine the actual safe yields of the springs. The discharges of four springs (L/s): Seesona, Shaamina, Bolo and Woyshaa are 2.6, 1.9, 12.8 and 1 respectively. The annual volumes (m^3/yr) estimated for Seesona, Shaamina, Bolo and Woysha are 81,993, 59,918, 403,660 and 31,536 respectively. The annual total discharges of the four springs were proposed to complement the existing supply system in order to balance the future supply and demand of the Town.

4. Discussion

Both the water supply and consumption were evaluated based on the annual water production and consumption using population data of the Town. The current water supply of the Town found to be 231,309 m^3/year. The current water consumption of different customer groups was also estimated. For private yard connections, public tap users, in-house connection, and the Town's average per capita per day the consumption rates were found to be 20.4, 6.2, 37 and 14.7 respectively. Compared to Universal Access Plan, the water supply target of the Town was 20 L/c/d. This indicates that the current water supply does not match the demand.

Despite the low water supply of the Town, the total water loss is found to be high; the water loss was found to be 34.4% of the total water production. Compared to the selected target for water loss which is 20%, the water loss of 34.4% has a negative impact on water supply to satisfy increasing demand and to increase revenue.

The current water supply coverage of the Town was at the level of 74%. Boditi Town was category III town of population size between 30,000-80,000 and the Town's target was to supply 20 L/c/d (MoWR, 2009). The long term (2012-1016), urban water supply coverage is expected to grow from 74% in 2002 to 100% in 2016 (MoWE, 2011). The water supply coverage value does not indicate whether the population has access to sufficient amount of water, but it was compared to minimum survival WHO and local standards of per capita per day water use. Performance indicator on water supply coverage remained below the selected target 100% of MoWE 2011.The Town has low domestic water use, has high demand, and the Supply should be increased. Hence, the performance level of water supply, demand, coverage and loss that obtained in this study was below the selected targets or below the standards recommended by Universal Access Plan (UAP). Based on the findings, the performance level of the Town's water supply system was below the selected targets or below the standards recommended by Universal Access Plan.

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Appendix- 1.Requirements and rating scales for option selection
1/ Reliability: 1/No reliability 2/ Little reliability 3/ Less than sufficient reliability 4/ Sufficient reliability 5/ More than sufficient reliability
2/ Benefits/Quality: 1/ Very poor (require extensive treatment) 2/ Poor (moderate treatment removal of iron and manganese) 3/ Fair (require some treatment, hardness removal) 4/ Good (require disinfection) 5/ Excellent (require no treatment).
3/Abstraction structures: 1/ requires pumps, reservoirs, pumps 2/ Reservoirs 3/ Pipe
4/ Risk factor: 1/ Difficult to locate 2/ Accessible 3/ easily accessible
5/Likely treatment: 1/Aeration, sedimentation, filtration, disinfection 2/ sedimentation, filtration, disinfection 3/ filtration, disinfection 5/ only disinfection.

Appendix-2: Volume of water produced by a BH= Discharge of a BH(L/s) X working time of a BH(seconds).

Table1:Monthly operation time and Volume produced by boreholes (July2011 to June 2012).

Water balance (Month 2011/12)	Boreholes and time of operation(hours)				Volume discharged/produced (m^3)				System input volume
	Faate BH (hr)	Keera BH (hr)	Chayna BH (hr)	Dooge BH(hr)	Faate BH (m^3)	Keera BH (m^3)	Chayna BH (m^3)	Dooge BH(m^3)	Volume Produced(m^3)
July	432:00	535:00	525:00	458:00	4665	5778	3780	3297	17,520
August	633:00	634:00	550:00	538:00	6836	6847	3960	3873	21,516
September	513:00	527:00	556:00	465:00	5540	5691	4003	3348	18,582
October	518:00	520:00	537:00	470:00	5594	5616	3866	3384	18,460
November	522:00	547:00	528:00	515:00	5637	5907	3801	3708	19,053
December	532:00	548:00	513:00	525:00	5745	5918	3693	3780	19,136
January	487:00	481:00	538:00	463:00	5259	5194	3873	3333	17,659
February	442:00	400:00	523:00	549:00	4773	4320	3765	3952	16,810
March	532:00	490:00	516:00	536:00	5745	5292	3715	3859	18,611
April	547:00	540:00	541:00	490:00	5907	5832	3895	3528	19,162
May	541:00	544:00	537:00	510:00	5842	5875	3866	3672	19,255
June	539:00	521:00	542:00	531:00	5821	5626	3902	3823	19,172
Total					67,364	67,896	46,119	43,557	224,936

Table2: Monthly operation time and Volume produced by boreholes (July 2012 to June 2013).

Water balance	Boreholes and time of operation(hours)				Volume discharged/produced(m^3)				
(Month 2012/2013)	Faate BH (hr)	Keera BH (hr)	Chayna BH (hr)	Dooge BH(hr)	Faate BH (m^3)	Keera BH (m^3)	Chayna BH (m^3)	Dooge BH (m^3)	Volumeproduced By BHs
July	548:00	554:00	510:00	442:00	5918	5983	3672	3182	18,755
August	580:00	563:00	575:00	533:00	6264	6080	4140	3837	20,321
September	549:00	475:00	525:00	527:00	5929	5130	3780	3794	18,633
October	540:00	547:00	502:00	518:00	5832	5907	3614	3729	19,082
November	530:00	490:00	535:00	580:00	5724	5292	3852	4176	19,044
December	522:00	548:00	550:00	565:00	5637	5918	3960	4068	19,583
January	570:00	541:00	545:00	534:00	6156	5812	3924	3844	19,736
February	561:00	495:00	524:00	558:00	6058	5346	3772	4017	19,193
March	520:00	545:00	530:00	561:00	5616	5886	3816	4039	19,357
April	523:00	513:00	563:00	525:00	5648	5540	4053	3780	19,021
May	540:00	530:00	571:00	531:00	5832	5724	4111	3823	19,490
June	535:00	525:00	522:00	540:00	5778	5670	3758	3888	19,094
Total					70,392	68,288	46,452	46,177	231,309